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TECHNICAL NOTE

No. 1421

EFFECT OF VARIATION IN DIAMETER AND PITCH OF RIVETS ON COMPRESSIVE STRENGTH OF PANELS WITH Z-SECTION STIFFENERS

PANELS OF VARIOUS LENGTHS WITH CLOSE STIFFENER SPACING

By Norris F. Dow and William A. Hickman

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

An experimental investigation is being conducted to determine the effect of varying the rivet diameter and pitch on the compressive strength of flat 24S-T aluminum-alloy panels with longitudinal Z-section stiffeners of the type for which design charts are available. So far the investigation has been limited to the region of the design charts in which the panels have the closest stiffener spacings and the smallest values of width-to-thickness ratio for the webs of the stiffeners. Tests of these panels showed that the effect of riveting on the strength of the panels depended on the type of failure. The strength of the short panels, which failed by local buckling, increased appreciably with either an increase in the diameter of the rivets or a decrease in the pitch of the rivets. The strength of the panels of intermediate length, which failed by a combination of local buckling and column bending, was less affected by changes in riveting. The strength of the long panels, which failed by column bending, showed some tendency to decrease with an increase in the strength of riveting. The decrease was probably caused by the greater initial curvature induced in the panel by the greater number or greater size of rivets.

INTRODUCTION

The design and analysis of sheet-stiffener panels for aircraft structures have been the subject of extensive experimental and theoretical investigation, but the determination of the size and pitch of rivets for attaching sheet to stiffeners is a problem that has not been adequately solved. In reference 1 charts and procedures are presented for the design of Z-stiffened panels to carry a given intensity of loading at a given panel length. The test data on which these design charts were based, however, were obtained for an arbitrary diameter and pitch of the rivets. An investigation is therefore being conducted in the Langley structures research laboratory of the NACA to determine the effect of a variation in the rivet diameter and pitch on the strength of flat 24S-T aluminum-alloy panels with longitudinal Z-section stiffeners of the type for which the design charts of reference 1 were prepared.

Results are presented of the second series of tests for the investigation. Some results of the first series of tests, reported in reference 2, are combined herein with the results of the second series. Since any number of combinations of rivet diameter and pitch are possible for any panel, the results of the tests made in these first two series can cover only a small region on the design charts of reference 1. The first series of tests (reference 2) covered the region in which the panels have the closest stiffener spacings, the smallest value of width-to-thickness ratio for the webs of the stiffeners, and such lengths that failure is by local buckling. The second series of tests, with which the present paper is concerned, covers the same region as the tests of reference 2 except for the limitation on the panel lengths.

SYMBOLS

L	length of specimen, inches
ρ	radius of gyration, inches
L/ρ	slenderness ratio
W	width of specimen, inches
b_S	spacing of stiffeners on sheet, inches
b_A	width of attachment flange of stiffeners, inches
b_W	width of web of stiffeners, inches
b_F	width of outstanding flange of stiffeners, inches
t_S	thickness of sheet, inches
t_W	thickness of web of stiffeners, inches

d diameter of rivets, inches

p pitch of rivets, inches

h depth of countersink for rivets, inches

σ_{cy} compressive yield stress for the material, ksi

$\bar{\sigma}_f$ average compressive stress at failing load for any specimen, ksi

c coefficient of end fixity as used in the Euler column formula

P_i compressive load per inch of panel width, kips/inch

δ initial longitudinal curvature of panel, inches

TEST SPECIMENS AND METHOD OF TESTING

The specimens consisted of 24S-T aluminum-alloy panels having longitudinal Z-section stiffeners as shown in figures 1 and 2. The nominal proportions of the stiffeners on all panels were identical. Two thicknesses of sheet were used to give two ratios of stiffener thickness to sheet thickness: $\frac{t_W}{t_S} = 1.00$ and 0.63. The proportions $\frac{b_S}{t_S} = 25$, $\frac{b_W}{t_W} = 20$, $\frac{b_A}{t_W} = 9.5$, and $\frac{b_F}{b_W} = 0.4$ were chosen to give the panels from the design charts of reference 1 that have the closest stiffener spacings and the smallest values of width-to-thickness ratio for the webs of the stiffeners. In order to allow for the larger rivets used in the present investigation, the value of $\frac{b_A}{t_W}$ for the panels was slightly larger than that used for those panels of reference 1 which had $\frac{t_W}{t_S} = 1.00$. Three panel lengths were investigated $\left(\frac{L}{\rho} = 40, 70, \text{ and } 120\right)$. The data of reference 2 were used to provide information regarding the strength of the panels at $\frac{L}{\rho} = 20$.

Tests were made to determine the material properties of the sheet used for the construction of the specimens. The maximum with-grain compressive yield stress σ_{cy} obtained for the material used for the construction of the specimens was 47.1 ksi. The minimum value of σ_{cy} obtained was 41.4 ksi. The average value of σ_{cy} obtained from the results of tests of stress-strain specimens cut from all the sheets of material used in the construction of the panels was 43.6 ksi. The foregoing values of σ_{cy} represent the with-grain properties of the flat-sheet material before forming.

The rivets used throughout the investigation were A17S-T flat-head rivets (AN442AD). Both the size and pitch of the rivets were varied for each ratio of sheet thickness to stiffener thickness as is shown in table 1. The minimum rivet pitch used in all cases was equal to three times the rivet diameter. On all panels the rivets were driven by the NACA flush-riveting process (reference 3) in which the rivet is inserted with the head opposite the countersunk end of the hole, the shank of the rivet is driven into the cavity formed by the countersink, and the excess material is removed with a milling tool. A countersink angle of 60° was used throughout. The depths of the countersink used are given in table 1.

Ultimate compressive loads for the specimens were determined in a hydraulic testing machine having an accuracy of one-half of one percent of the load. The ends of the specimens were ground flat and parallel before testing to insure a uniform distribution of load over the panel.

RESULTS AND DISCUSSION

Because the present investigation covers only a small region on the design charts of reference 1, no attempt is made herein to present the data by plotting the average stress at failing load $\bar{\sigma}_f$ against the parameter $\frac{P_i}{L/\sqrt{c}}$, as in reference 1. Instead, in order to present the results in a manner similar to that of reference 2, $\bar{\sigma}_f$ is plotted in figure 3 against the ratio of rivet diameter to the sum of the thicknesses of sheet and stiffener $\frac{d}{t_S + t_W}$. Numerical values of $\bar{\sigma}_f$ and $\frac{P_i}{L/\sqrt{c}}$, however, are listed in table 1.

Figure 3 shows that, for both values of t_W/t_S investigated, the compressive strength of the short panels $\left(\frac{L}{\rho} = 20 \text{ or } 40\right)$, which failed by local buckling, increased appreciably with either an increase in the diameter of the rivets or a decrease in the pitch of the rivets. The strength of the panels of intermediate length $\left(\frac{L}{\rho} = 70\right)$, which failed by a combination of local buckling and column bending, was less affected by changes in riveting. The strength of the long panels $\left(\frac{L}{\rho} = 120\right)$, which failed by column bending, was not increased by an increase in the strength of riveting. In fact, the strength of the long panel tended to decrease with an increase in the strength of riveting.

The tendency of the strength of the long panels to decrease at large values of $\frac{d}{t_S + t_W}$ was probably caused by the relatively large values of initial longitudinal curvature of the more strongly riveted panels. (See table 1 for values of initial panel curvature.) As the stiffeners and sheet are riveted together, the rivets, and hence the sheet, tend to expand and thus induce curvature in the panel. The amount of curvature increases with an increase in the number of rivets and the diameter of the rivets. The more strongly riveted panels, accordingly, may be expected to have the greater initial curvatures, which may be expected to decrease the column strength of the panels.

CONCLUDING REMARKS

Results are presented of tests to determine the effect of varying rivet diameter and rivet pitch on the compressive strength of 24S-T aluminum-alloy panels with Z-section stiffeners. The panels were selected on the basis of available design charts, and the panel proportions were limited to the region of these charts in which the panels have the closest stiffener spacings and the smallest values of width-to-thickness ratio for the webs of the stiffeners. The results showed that the effect of riveting on the strength of panels depended on the type of failure. The strength of the short panels, which failed by local buckling, increased appreciably with either an increase in the diameter of the rivets or a decrease in the rivet pitch. The strength of the panels of intermediate length, which failed by a combination of local buckling and column bending, was less affected by changes in riveting. The strength of the long panels which failed by column bending showed some tendency to decrease with an increase in the strength of riveting, probably as a result of the greater initial curvature induced in the panel by the greater number or greater size of rivets.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., June 19, 1947

REFERENCES

1. Schuette, Evan H.: Charts for the Minimum-Weight Design of 24S-T Aluminum-Alloy Flat Compression Panels with Longitudinal Z-Section Stiffeners. NACA ARR No. L5F15, 1945.

2. Dow, Norris F., and Hickman, William A.: Effect of Variation in Diameter and Pitch of Rivets on Compressive Strength of Panels with Z-Section Stiffeners. I - Panels with Close Stiffener Spacing That Fail by Local Buckling. NACA RB No. L5G03, 1945.

3. Gottlieb, Robert: Test Data on the Shear Strength of Machine Countersunk-Riveted Joints Assembled by an NACA Flush-Riveting Procedure. NACA RB, Dec. 1942.

TABLE 1.— NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS

SHOWING EFFECTS OF VARYING RIVET PITCH AND RIVET DIAMETER

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
$t_S = 0.064$ in.; $b_S = 1.60$ in.; $L = 10.40$ in.; $W = 8.64$ in.; $\frac{t_W}{t_S} = 1.00$; $\frac{b_S}{t_S} = 25$; $\frac{b_W}{t_W} = 20$; $\frac{L}{\rho} = 20$				
1/16	0.035	3/16	43.050	1.233
		3/8	41.450	1.180
		5/8	[a]36.855	1.013
		15/16	[a]38.380	1.093
		$1\frac{5}{16}$	29.300	.840
		$1\frac{3}{4}$	26.700	.768
3/32	.040	9/32	44.800	1.303
		3/8	43.500	1.245
		5/8	[a]38.070	1.069
		15/16	[a]40.035	1.140
		$1\frac{5}{16}$	33.400	.950
		$1\frac{3}{4}$	30.700	.891
1/8	.050	3/8	44.600	1.317
		5/8	[a]43.735	1.227
		15/16	[a]41.710	1.186
		$1\frac{5}{16}$	34.750	.990
		$1\frac{3}{4}$	32.200	.856
5/32	.060	15/32	45.000	1.318
		5/8	43.870	1.197
		15/16	40.500	1.142
		$1\frac{5}{16}$	36.100	1.032
		$1\frac{3}{4}$	[a]33.800	.973
3/16	.065	9/16	45.340	1.329
		5/8	44.700	1.232
		15/16	40.850	1.160
		$1\frac{5}{16}$	37.600	1.077
		$1\frac{3}{4}$	[a]33.800	.968
1/4	065	3/4	44.485	1.272
		15/16	44.485	1.290
		$1\frac{5}{16}$	38.900	1.104
		$1\frac{3}{4}$	35.350	1.022

[a]Average of two tests.

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TABLE 1.– NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Initial longitudinal curvature, δ (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
t_S = 0.064 in.; b_S = 1.60 in.; L = 20.80 in.; W = 8.64 in; $\frac{t_W}{t_S}$ = 1.00; $\frac{b_S}{t_S}$ = 25; $\frac{b_W}{t_W}$ = 20; $\frac{L}{\rho}$ = 40					
1/16	0.035	3/16	0.02	40.910	0.583
		3/8	.03	39.710	.556
		5/8	.01	38.180	.545
		15/16	.03	35.870	.511
		$1\frac{5}{16}$	.02	32.760	.472
		$1\frac{3}{4}$	.01	26.730	.382
3/32	.040	9/32	.06	41.520	.599
		3/8	.02	40.400	.574
		5/8	.02	39.010	.554
		15/16	.04	37.820	.545
		$1\frac{5}{16}$	.00	34.570	.503
		$1\frac{3}{4}$	.01	28.210	.400
1/8	.050	3/8	.03	41.440	.593
		5/8	.03	40.020	.568
		15/16	.02	38.690	.550
		$1\frac{5}{16}$	.01	34.550	.490
		$1\frac{3}{4}$	.01	28.950	.420
5/32	.060	15/32	.03	39.760	.573
		5/8	.03	[a]40.650	.579
		15/16	.02	[a]40.335	.576
		$1\frac{5}{16}$	.01	35.480	.511
		$1\frac{3}{4}$	.01	29.920	.429
3/16	.065	9/16	.03	39.950	.569
		5/8	.06	[a]40.275	.574
		15/16	.04	[a]39.865	.563
		$1\frac{5}{16}$	.03	36.310	.522
		$1\frac{3}{4}$	.01	30.550	.443
1/4	.065	3/4	.07	41.530	.608
		15/16	.04	40.970	.584
		$1\frac{5}{16}$	.05	37.040	.519
		$1\frac{3}{4}$	.04	32.830	.460

[a]Average of two tests.

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TABLE 1.– NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Initial longitudinal curvature, δ (in.)	Average stress at failing load, $\overline{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
$t_S = 0.064$ in.; $b_S = 1.60$ in.; $L = 36.40$ in.; $W = 8.64$ in.; $\frac{t_W}{t_S} = 1.00$; $\frac{b_S}{t_S} = 25$; $\frac{b_W}{t_W} = 20$; $\frac{L}{\rho} = 70$					
1/16	0.035	3/16	0.04	32.390	0.262
		3/8	.03	34.220	.279
		5/8	.01	33.570	.269
		15/16	.03	33.490	.276
		$1\frac{5}{16}$	.03	30.050	.244
		$1\frac{3}{4}$	.02	22.870	.183
3/32	.040	9/32	.06	32.980	.268
		3/8	.03	[a]33.555	.272
		5/8	.04	34.320	.278
		15/16	.02	36.040	.294
		$1\frac{5}{16}$	.02	31.820	.258
		$1\frac{3}{4}$	.02	28.070	.225
1/8	.050	3/8	.05	[a]34.105	.280
		15/32	.04	33.540	.274
		5/8	.05	[a]34.405	.278
		15/16	.04	[a]34.600	.275
		$1\frac{5}{16}$	.04	32.500	.263
		$1\frac{3}{4}$	.03	28.190	.231
5/32	.060	15/32	.11	31.100	.256
		5/8	.07	33.780	.276
		15/16	.10	[a]31.475	.257
		$1\frac{5}{16}$	.08	[a]31.950	.262
		$1\frac{3}{4}$	.04	29.010	.236
3/16	.065	9/16	.12	30.710	.249
		5/8	.08	[a]32.445	.260
		15/16	.10	[b]31.790	.260
		$1\frac{5}{16}$	.05	[a]32.300	.263
		$1\frac{3}{4}$	.06	[a]27.750	.220
1/4	.065	3/4	.14	[a]27.920	.224
		15/16	.16	27.970	.232
		$1\frac{5}{16}$	.14	[a]27.755	.219
		$1\frac{3}{4}$	.07	27.950	.227

[a]Average of two tests.
[b]Average of three tests.

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TABLE 1.– NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Initial longitudinal curvature, δ (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
$t_S = 0.064$ in.; $b_S = 1.60$ in.; $L = 62.40$ in.; $W = 8.64$ in.; $\frac{t_W}{t_S} = 1.00$; $\frac{b_S}{t_S} = 25$; $\frac{b_W}{t_W} = 20$; $\frac{L}{\rho} = 120$					
1/16	0.035	3/16	0.07	18.320	0.087
		3/8	.10	18.930	.090
		5/8	.03	19.570	.092
		15/16	.02	20.390	.098
		$1\frac{5}{16}$	.02	18.890	.089
		$1\frac{3}{4}$	.01	20.870	.100
3/32	.040	9/32	.02	19.940	.094
		3/8	.05	[a]19.460	.092
		5/8	.07	20.310	.098
		15/16	.07	19.070	.092
		$1\frac{5}{16}$	.06	19.895	.096
		$1\frac{3}{4}$	.03	19.970	.096
1/8	.050	3/8	.09	18.960	.091
		5/8	.06	19.620	.094
		15/16	.03	20.240	.097
		$1\frac{5}{16}$	.03	20.600	.100
		$1\frac{3}{4}$	.05	20.370	.098
5/32	.060	15/32	.23	11.064	.054
		5/8	.04	19.430	.093
		15/16	.07	[a]18.885	.091
		$1\frac{5}{16}$	.03	19.670	.095
		$1\frac{3}{4}$	.05	19.070	.091
3/16	.065	9/16	.15	16.310	.073
		5/8	.14	16.670	.079
		15/16	.14	16.600	.080
		$1\frac{5}{16}$	.03	18.900	.090
		$1\frac{3}{4}$	.02	18.770	.091
1/4	.065	3/4	.32	9.170	.045
		15/16	.24	8.470	.041
		$1\frac{5}{16}$	.24	12.110	.057
		$1\frac{3}{4}$	.29	9.540	.046

[a]Average of two tests.

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TABLE 1.– NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
$t_S = 0.102$ in.; $b_S = 2.55$ in.; $L = 9.44$ in.; $W = 13.39$ in.; $\frac{t_W}{t_S} = 0.63$; $\frac{b_S}{t_S} = 25$; $\frac{b_W}{t_W} = 20$; $\frac{L}{\rho} = 20$				
3/32	0.050	9/32	42.300	1.412
		9/16	39.300	1.288
		7/8	38.170	1.218
		1 7/32	35.400	1.158
		1 19/32	34.500	1.129
		2	30.000	.984
1/8	.060	3/8	43.800	1.445
		9/16	40.400	1.321
		7/8	39.700	1.263
		1 7/32	37.800	1.237
		1 19/32	35.500	1.167
		2	30.240	.984
5/32	.070	15/32	[a]43.590	1.431
		9/16	[a]42.335	1.388
		7/8	41.050	1.310
		1 7/32	37.850	1.236
		1 19/32	35.750	1.168
		2	31.800	1.049
3/16	.080	9/16	[a]45.150	1.451
		7/8	[b]41.150	1.327
		1 7/32	38.800	1.263
		1 19/32	38.150	1.253
		2	31.900	1.042
1/4	.090	3/4	44.050	1.471
		7/8	[a]43.000	1.378
		1 7/32	40.700	1.329
		1 19/32	39.800	1.307
		2	34.100	1.120

[a]Average of two tests.
[b]Average of three tests.

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TABLE 1.– NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Initial longitudinal curvature, δ (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
$t_S = 0.102$ in.; $b_S = 2.55$ in.; $L = 18.88$ in.; $W = 13.39$ in.; $\frac{t_W}{t_S} = 0.63$; $\frac{b_S}{t_S} = 25$; $\frac{b_W}{t_W} = 20$; $\frac{L}{\rho} = 40$					
3/32	0.050	9/32	0.02	42.480	0.698
		9/16	.02	40.460	.661
		7/8	.01	36.670	.589
		$1\frac{7}{32}$	.01	35.340	.572
		$1\frac{19}{32}$	.01	33.790	.544
		2	.01	30.100	.488
1/8	.060	3/8	.01	41.780	.693
		9/16	.01	41.680	.686
		7/8	.01	40.500	.655
		$1\frac{7}{32}$	.01	36.300	.586
		$1\frac{19}{32}$	.01	35.040	.579
		2	.01	30.600	.491
5/32	.070	15/32	.03	42.840	.696
		9/16	.02	41.370	.659
		7/8	.02	40.620	.654
		$1\frac{7}{32}$	.02	36.770	.589
		$1\frac{19}{32}$	.01	36.100	.589
		2	.01	31.780	.506
3/16	.080	9/16	.04	43.130	.715
		7/8	.02	41.010	.663
		$1\frac{7}{32}$	.05	38.550	.615
		$1\frac{19}{32}$	.03	36.520	.598
		2	.03	32.550	.526
1/4	.090	3/4	.03	43.210	.705
		7/8	.02	42.340	.683
		$1\frac{7}{32}$	.04	[a]39.445	.655
		$1\frac{19}{32}$	.03	38.270	.632
		2	.01	33.870	.552

[a]Average of two tests.

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TABLE 1.— NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS — Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Initial longitudinal curvature, δ (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
$t_S = 0.102$ in.; $b_S = 2.55$ in.; $L = 33.04$ in.; $W = 13.39$ in.; $\frac{t_W}{t_S} = 0.63$; $\frac{b_S}{t_S} = 25$; $\frac{b_W}{t_W} = 20$; $\frac{L}{\rho} = 70$					
3/32	0.050	9/32	0.05	34.540	0.326
		9/16	.03	36.090	.343
		7/8	.02	33.060	.315
		$1\frac{7}{32}$	.02	33.640	.318
		$1\frac{19}{32}$	.02	31.380	.296
		2	.02	29.500	.274
1/8	.060	3/8	.02	35.980	.336
		9/16	.01	35.590	.334
		7/8	.02	34.660	.327
		$1\frac{7}{32}$	.02	35.140	.333
		$1\frac{19}{32}$	.02	34.830	.330
		2	.01	32.970	.311
5/32	.070	15/32	.03	34.480	.327
		9/16	.02	37.120	.349
		7/8	.02	35.340	.334
		$1\frac{7}{32}$	.03	36.160	.339
		$1\frac{19}{32}$	.02	35.470	.332
		2	.02	33.470	.315
3/16	.080	9/16	.03	34.900	.328
		7/8	.05	34.960	.332
		$1\frac{7}{32}$	.07	34.360	.326
		$1\frac{19}{32}$	.03	34.570	.323
		2	.05	33.360	.316
1/4	.090	3/4	.13	31.100	.294
		7/8	.06	33.260	.313
		$1\frac{7}{32}$	.03	[a]37.130	.353
		$1\frac{19}{32}$	.07	34.430	.326
		2	.07	33.650	.325

[a] $\frac{L}{\rho} = 59$

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TABLE 1.– NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Concluded

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Initial longitudinal curvature, δ (in.)	Average stress at failing load, $\overline{\sigma}_f$ (ksi)	$\frac{P_f}{L/\sqrt{c}}$ (ksi)
$t_S = 0.102$ in.; $b_S = 2.55$ in.; $L = 56.64$ in.; $W = 13.39$ in.; $\frac{t_W}{t_S} = 0.63$; $\frac{b_S}{t_S} = 25$; $\frac{b_W}{t_W} = 20$; $\frac{L}{\rho} = 120$					
3/32	0.050	9/32	0.04	22.110	0.122
		9/16	.11	19.920	.111
		7/8	.14	22.710	.125
		$1\frac{7}{32}$	.05	19.920	.111
		$1\frac{19}{32}$	.06	20.200	.111
		2	.08	21.570	.121
1/8	.060	3/8	.08	21.610	.119
		9/16	.09	22.680	.125
		7/8	.08	20.990	.117
		$1\frac{7}{32}$	.10	21.060	.118
		$1\frac{19}{32}$	.03	19.580	.109
		2	.04	20.870	.116
5/32	.070	15/32	.05	20.900	.115
		9/16	.03	21.840	.121
		7/8	.02	20.970	.116
		$1\frac{7}{32}$	.03	21.920	.122
		$1\frac{19}{32}$	.04	19.690	.109
		2	.04	22.040	.123
3/16	.080	9/16	.09	20.440	.113
		7/8	.08	19.940	.111
		$1\frac{7}{32}$	.02	20.880	.117
		$1\frac{19}{32}$	.05	20.410	.114
		2	.07	18.845	.104
1/4	.090	3/4	.21	13.400	.075
		7/8	.17	14.340	.080
		$1\frac{7}{32}$	.15	18.010	.101
		$1\frac{19}{32}$	.15	17.650	.099
		2	.03	18.030	.099

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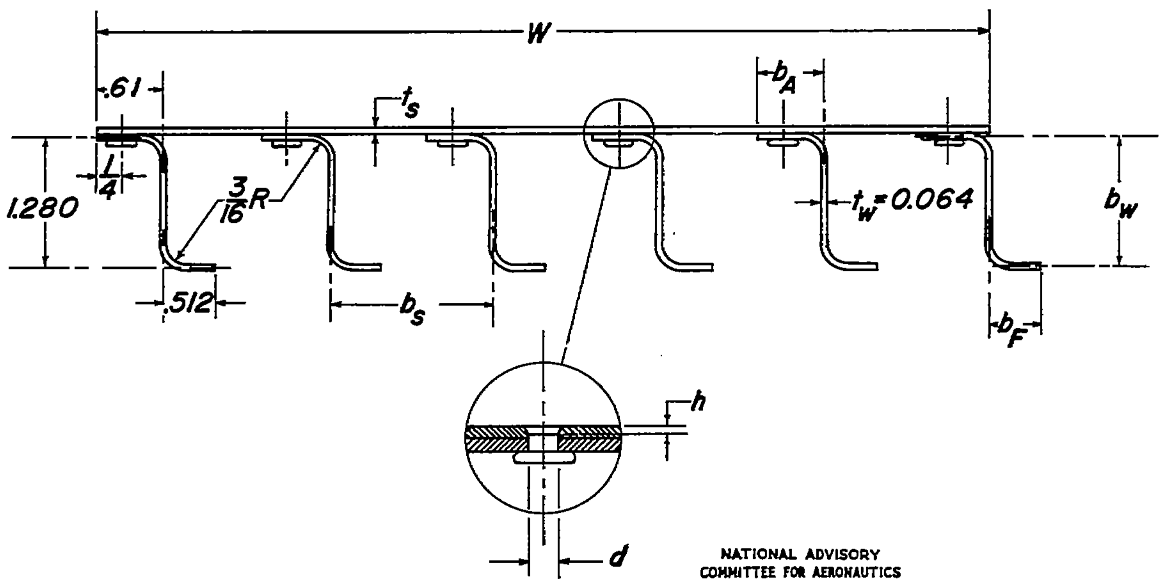


Figure 1.– Cross section of test specimens.

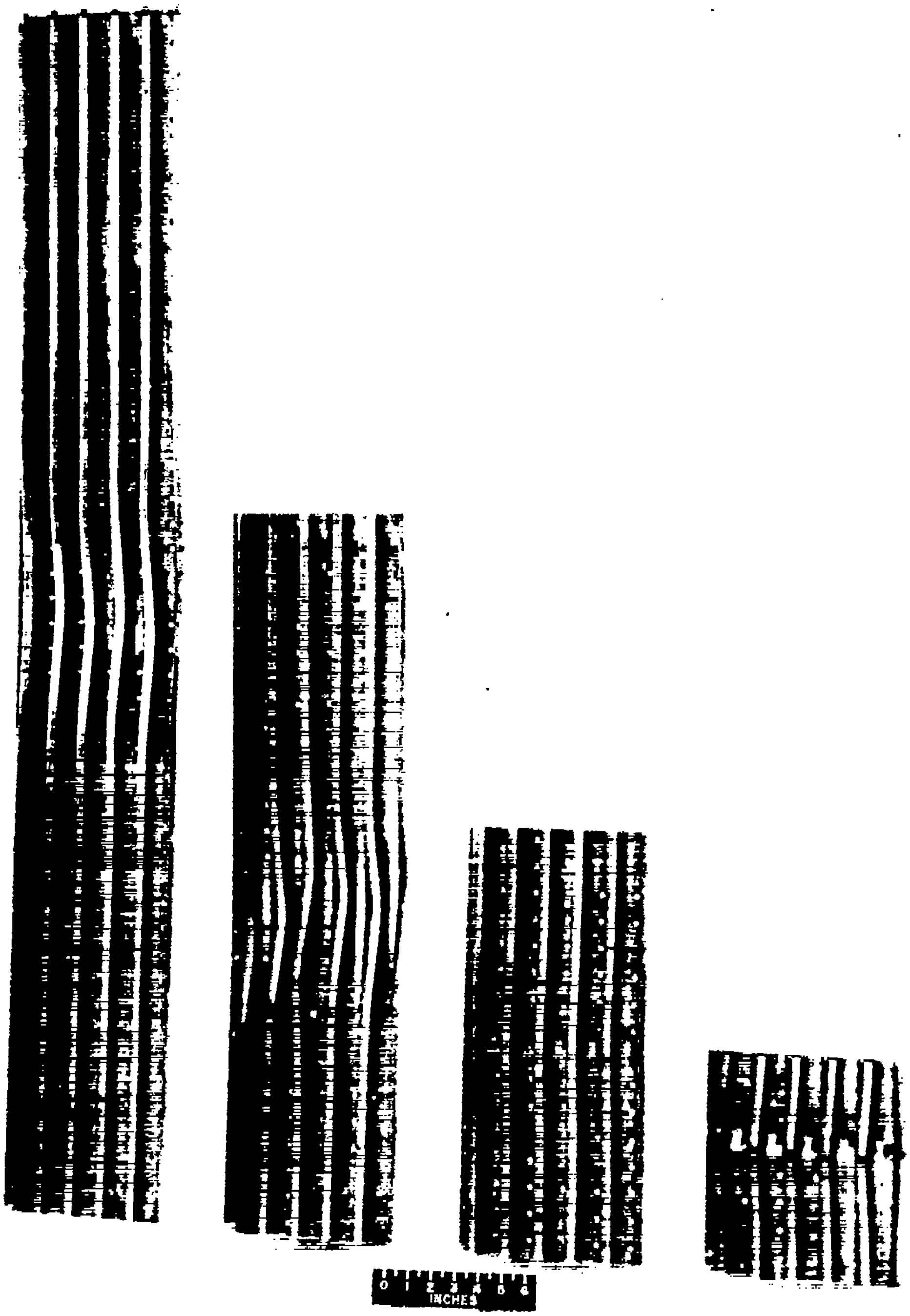
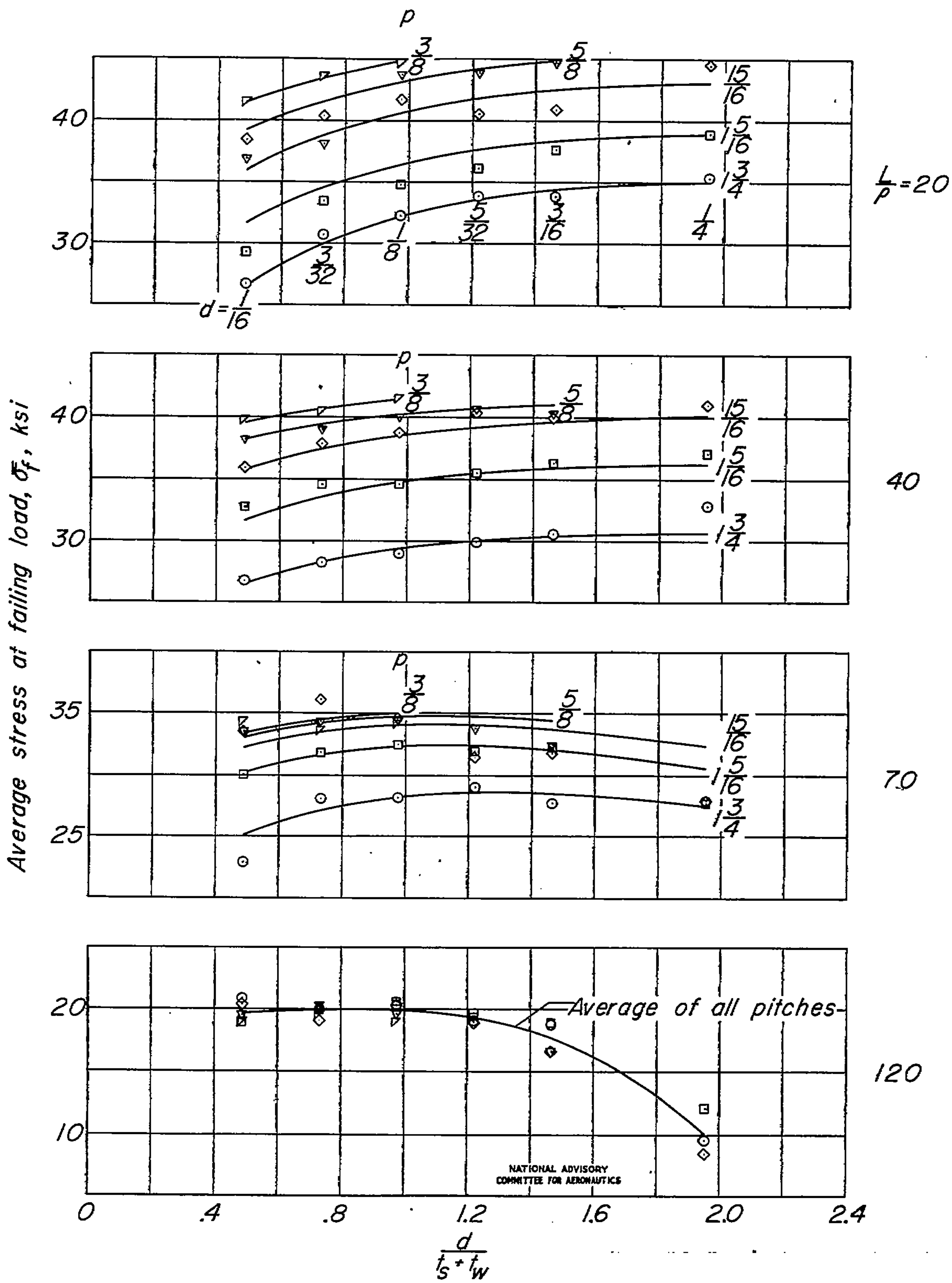
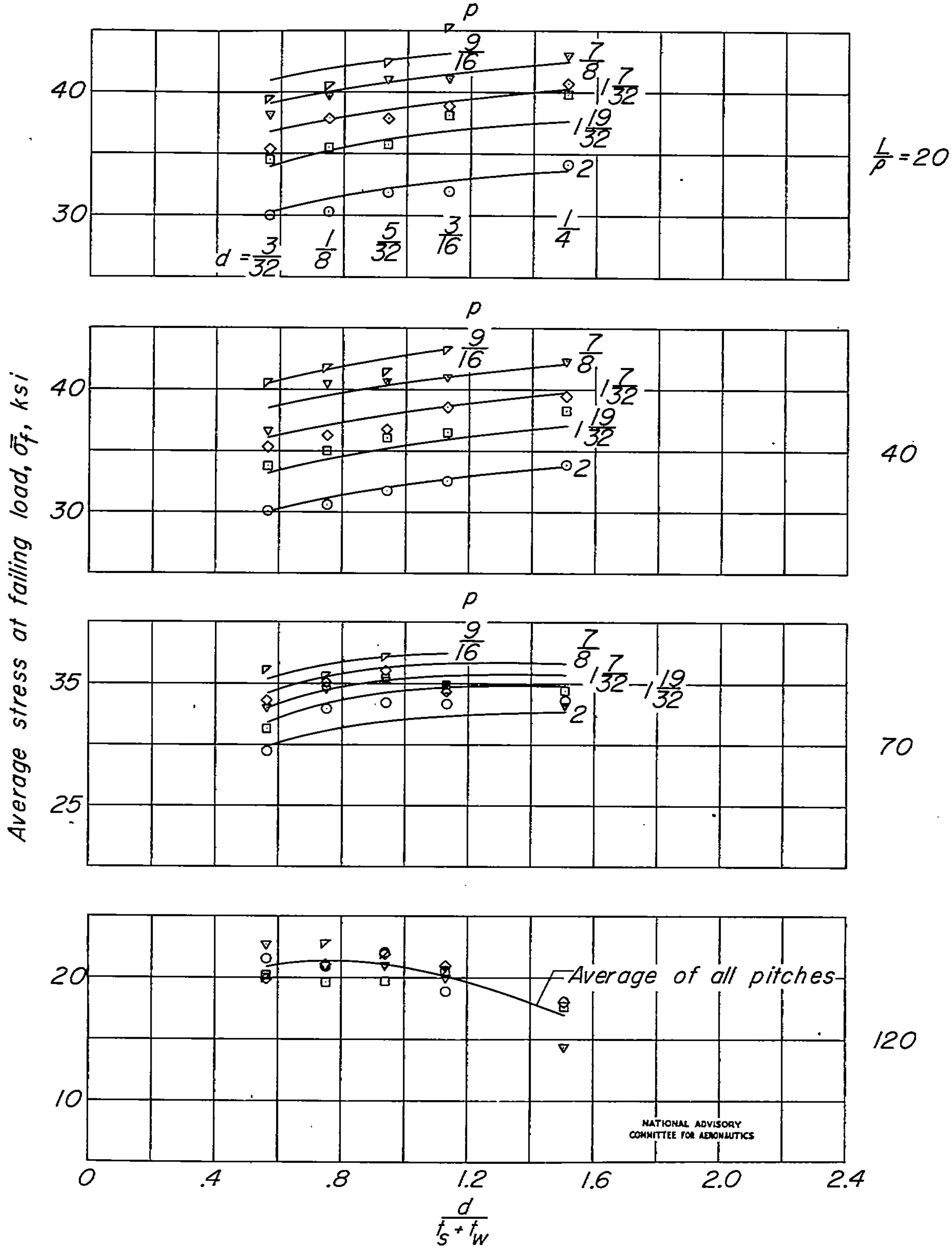


Figure 2.- Test specimens after failure.



(a) $\frac{t_w}{t_s} = 1.00$; $t_s = 0.064$.

Figure 3.– Variation in compressive strength of panels with rivet diameter.



(b) $\frac{t_w}{t_s} = 0.63$, $t_s = 0.102$.

Figure 3.– Concluded.